SSR cavity processing plans at FNAL/ANL and IJCLab

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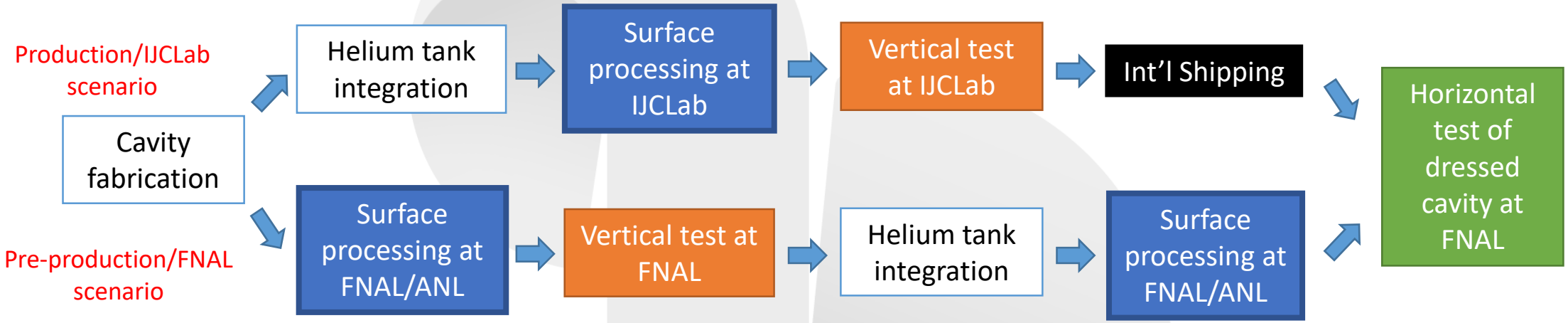
On behalf of all contributors to PIP-II SSR at IJCLab/FNAL/ANL/DAE

OUTLINE

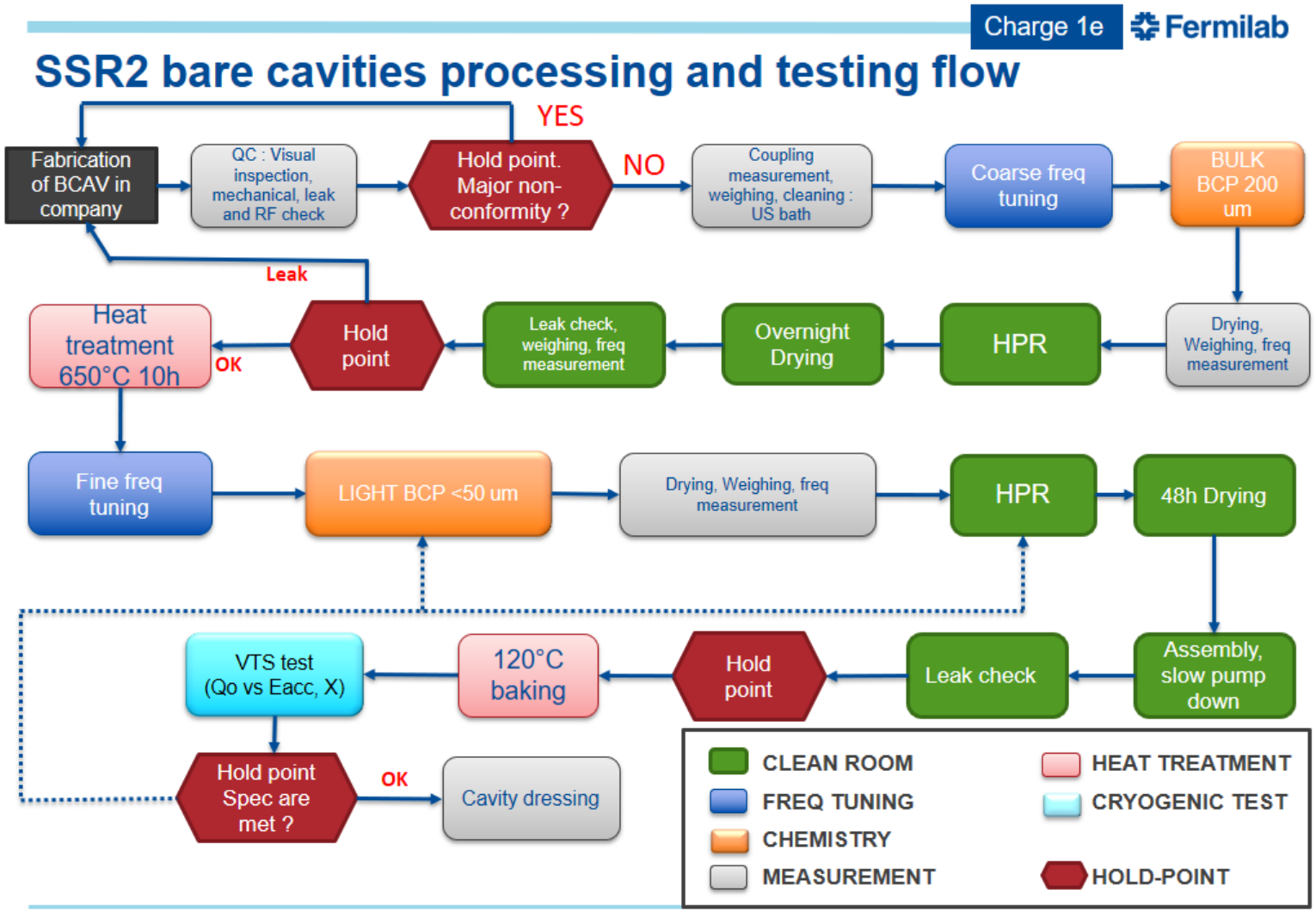
- Preliminary cavity flow chart for SSR cavity surface processing
- Description and acceptance criteria for specific steps :
  - BCP
  - H-degassing
  - HPR + drying + assembly
  - Frequency tuning
  - Low temperature baking
  - Vertical test
  - Horizontal test

Preliminary cavity flow chart for cavity surface processing

- Base-line flow chart already suggested during FDR of pre-production SSR2 cavity
- Flow charts are aligned between FNAL/ANL and IJCLab even though cavity configuration is different
  - FNAL/ANL => Bare Cavity
  - IJCLab => Jacketed Cavity
- FNAL/ANL flow chart is extended after tank integration but is necessary to fully qualify pre-production cavities.
- IJCLab flow chart is short-cutted but is production-like (no bare cavity processing as no possibilities of dunk test)



Preliminary cavity flow chart for cavity surface processing



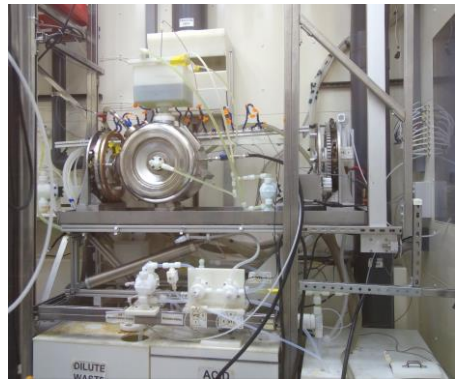
Description and acceptance criteria for specific steps

- BCP treatment
  - Remove damaged layer from fabrication

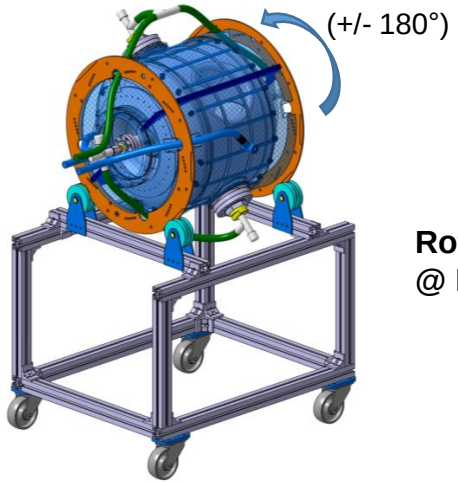
REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA
Average removal	Weighing Ultrasonic probe	Average removal (bulk) : 120-180 um Average removal (flash) : ~ 25 um
Maximum local removal	Ultrasonic probe	< 400 um
Minimum thickness	Ultrasonic probe	> 3.75 mm
Acid bath/cavity cooling	Temperature monitoring	< 15°C
Defect free surface	Optical inspection (endoscop)	No visible defects
No leak	Leak detection	< 10^{E}-10 mbar.l.s^{-1}

  - Paths for optimization :
    - Rotational BCP : improve homogeneity of material removal, avoid appearance of surface defects : grooves, white drips, …

Etching lab @ IJCLab



Etching lab @ ANL



Rotational BCP for SSR2 @ IJCLab

Description and acceptance criteria for specific steps

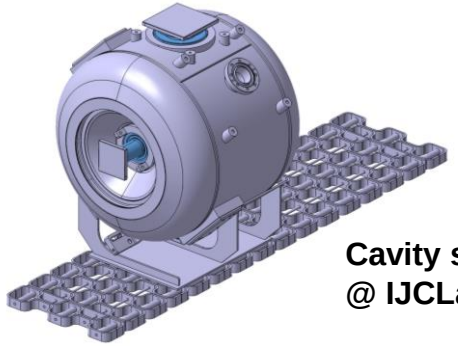
- H-Degassing
  - Degas hydrogen out from Niobium.
  - Release material stress

REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA
Heat above 600°C during 10h	Temperature monitoring	Temperature cycle is normal
Degas hydrogen	RGA scan	Observe degassing peak of H H Partial Pressure decreased of
Limit mechanical stress	Heating steps Heating ramp	Hold 1h at 300°C dT/dt < 2°C/min
No pollution with hydro-carbons	RGA scan	HC Partial Pressure below ??
Defect free	Optical inspection (endoscop)	No visible defects
No leak (RF and helium volume)	Leak detection	< 10^{E}-10 mbar.l.s^{-1}

Furnace @ IJCLab

Furnace @ FNAL

- Paths for optimization :
  - Remove flash BCP after H-degassing
  - Increase temperature to foster re-cristallization (800°C) ?



Cavity support for furnace @ IJCLab

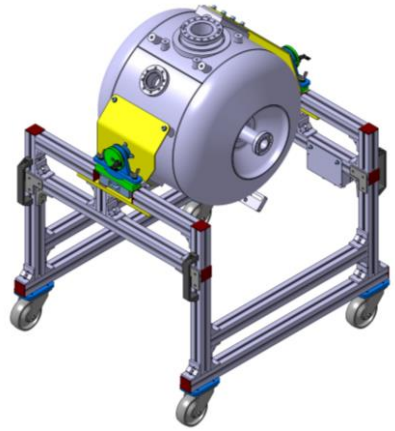
Description and acceptance criteria for specific steps

- HPR + drying + assembly
  - Remove any surface pollution from the surface
  - Required before and after Hydrogen degassing

REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA
Hit all surface with water jet	TBD	Rinsing time > ??h Nozzle translation speed < ?? mm/s
Drying of surfaces before assembly		Drying time > 48h
Maintain cavity cleanliness during assembly	Parts degreasing Particle counting on parts (N2 blowing)	Number of particle below 0.5um : ??
Maintain cavity cleanliness during pump down	Slow pump down	< 1mbar.s^{-1} down to 1 mbar

HPR unit @ IJCLab

HPR unit @ FNAL



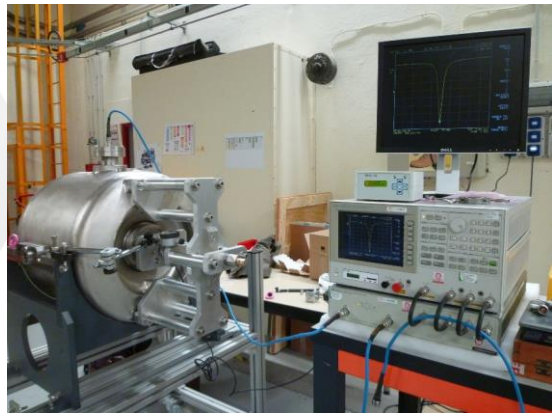
HPR cart for SSR2 @ IJCLab

- Paths for optimization :
  - In-line or sampled Particle monitoring in water during HPR
  - Dynamic drying (heat up cavity before/after assembly ?

Description and acceptance criteria for specific steps

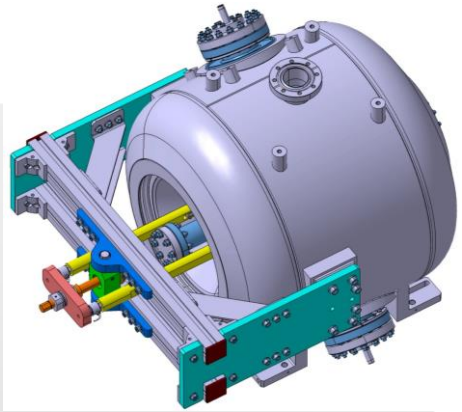
- Frequency tuning
  - Reach frequency target
  - Measure cavity stiffness

REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA
Reach frequency target	VNA	Target +/- 30 kHz ??
Evaluate longitudinal stiffness	Force gauge Displacement gauge	< 16 kN/mm
Evaluate tuning sensitivity	VNA Displacement gauge	> 250 kHz/mm



Frequency tuning of MYRRHA @ IJCLab

Frequency tuning of SSR1 @ FNAL



Frequency tuning of SSR2 @ IJCLab

Description and acceptance criteria for specific steps

- Low temperature baking
  - Reduce multipacting
  - Improve Q-slope (to be demonstrated)

REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA
Heat above 120°C during 48h	Temperature monitoring	Temperature cycle is normal
Reduction of H_2O partial pressure	RGA scan	$P_{H2Ofinal} = P_{H20before}/10$ (??)

LTB set-up @ IJCLab

LTB set-up @ FNAL

- Paths for optimization :
  - No LTB ? (not required if no Q-slope at operating gradient and very limited multipacting)

Description and acceptance criteria for specific steps

- Vertical testing
  - Validation of cleaning procedure
  - Validation of cavity performance

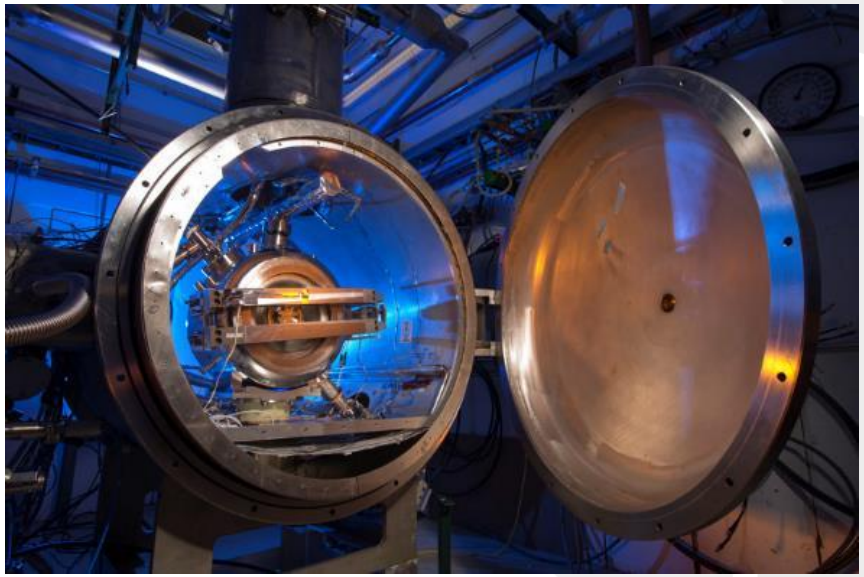
REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA (jacketed)
Vacuum level before cooling down and at 2K	Vacuum gauge	< 1^{E}-7 mbar
Achieve minimum gradient	RF measurement	13.7 MV/m
Qo at 5 MV (11.5 MV/m)	RF measurement	> $8^{E}9$ (jacketed) > $9^{E}9$ (bare)
Frequency at 2K at 5 MV (11.5 MV/m)	Frequency meter	325 MHz +/- 65 kHz (without tuner) 325 MHz (with tuner)
No field emission at 5 MV	X-rays detector	< 1 uSv/h in beam tube axis
No multipacting up to 5 MV (after RF processing)	RF measurement X-rays detector	Pick-up signal stable < 1 uSv/h in beam tube axis
Sensitivity to Lhe pressure (with tuner)	Frequency meter	< 25 Hz/mbar (with tuner)
Sensitivity to Lorentz forces (with tuner)	Frequency meter RF measurement	< 5 Hz/$(MV/m)^2$ (with tuner)
Field probe level @ 5 MV	RF measurement	300 mW +/- 200 mW

Vertical cryostat @ IJCLab

Vertical cryostat @ FNAL

Description and acceptance criteria for specific steps

- Horizontal testing
  - Validation of cavity performance with HPC and Tuner
  - Validation of HPC assembly procedure



Horizontal cryostat @ FNAL

REQUIREMENTS	TECHNIQUE	ACCEPTANCE CRITERIA (jacketed)
Vacuum level before cooling down and at 2K	Vacuum gauge	< 1E-7 mbar
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Qo at 5 MV (11.5 MV/m)	RF measurement	> 8E9 (jacketed)
Frequency at 2K at 5 MV (11.5 MV/m)	Frequency meter	325 MHz (with tuner)
No field emission at 5 MV	X-rays detector	< 1 uSv/h in beam tube axis
No multipacting up to 5 MV (after RF processing)	RF measurement X-rays detector	Pick-up signal stable < 1 uSv/h in beam tube axis
Sensitivity to LHe pressure (with tuner)	Frequency meter Pressure gauge	< 25 Hz/mbar
Sensitivity to Lorentz forces (with tuner)	Frequency meter RF measurement	< 5 Hz/(MV/m)^2
Field probe level @ 5 MV	RF measurement	300 mW +/- 200 mW
Operating cavity Q-loaded	VNA	5.05E6 +/- 25%
Slow tuner frequency range	Frequency meter	> 130 kHz
Fast tuner frequency range	Frequency meter	> 700 Hz
Hysteresis	Frequency meter	< ?? Hz

Conclusion

- Preliminary cavity flow chart has been developped jointly for SSR2 FDR
  - Same flow chart should be applied by all involved partners.
  - Some differences can exist in procedures because of cavity configuration (bare/jacketed) and facilities.
- Acceptance criteria for each step should be jointly defined
  - A preliminary list is suggested and should be finalized before delivery of pre-production cavities.
  - The flow chart and acceptance criteria have to be updated/adapted during pre-production phase and finalized to be validated at FDR of production cavities.
  - Some paths of optimization have been identified and will be investigated on pre-production cavities.

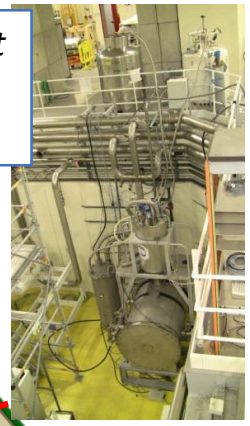
BACK-UP SLIDES

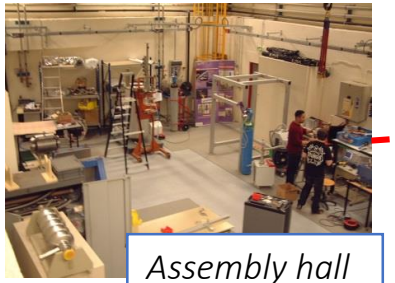
Processing capabilities at IJCLab : SUPRATECH Platform

Vacuum furnace

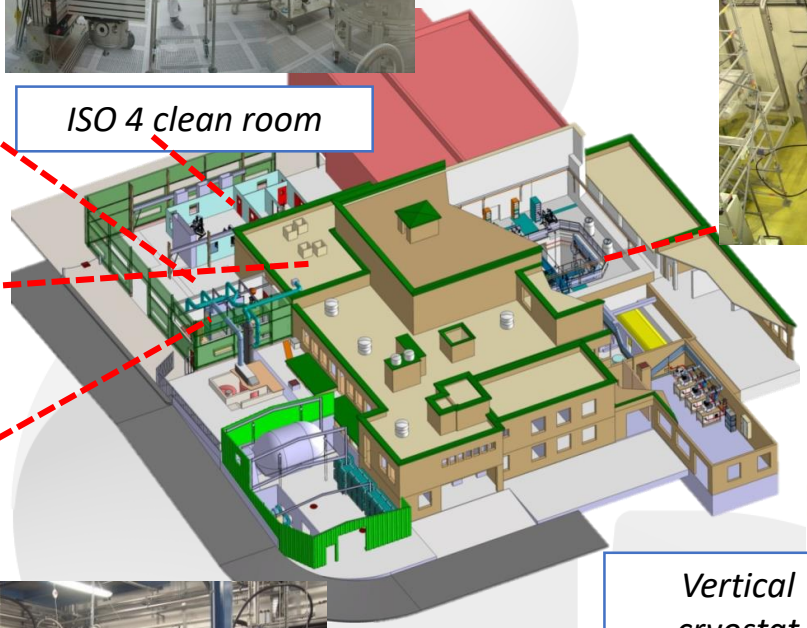
ISO 4 clean room

Cryogenic test hall for cryomodules





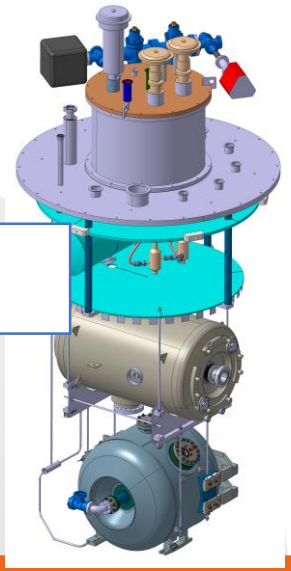
Assembly hall



Chemical etching lab (BCP only)

Helium liquefier

Vertical cryostat



+ Material science lab

- GXRD
- SIMS
- Confocal microscope
- SEM (EDS, EBSD)
- SEY measurement

+ Other

- RRR measurement (Supratech)
- Conductivity (Supratech)
- TEM (Jannus Platform)

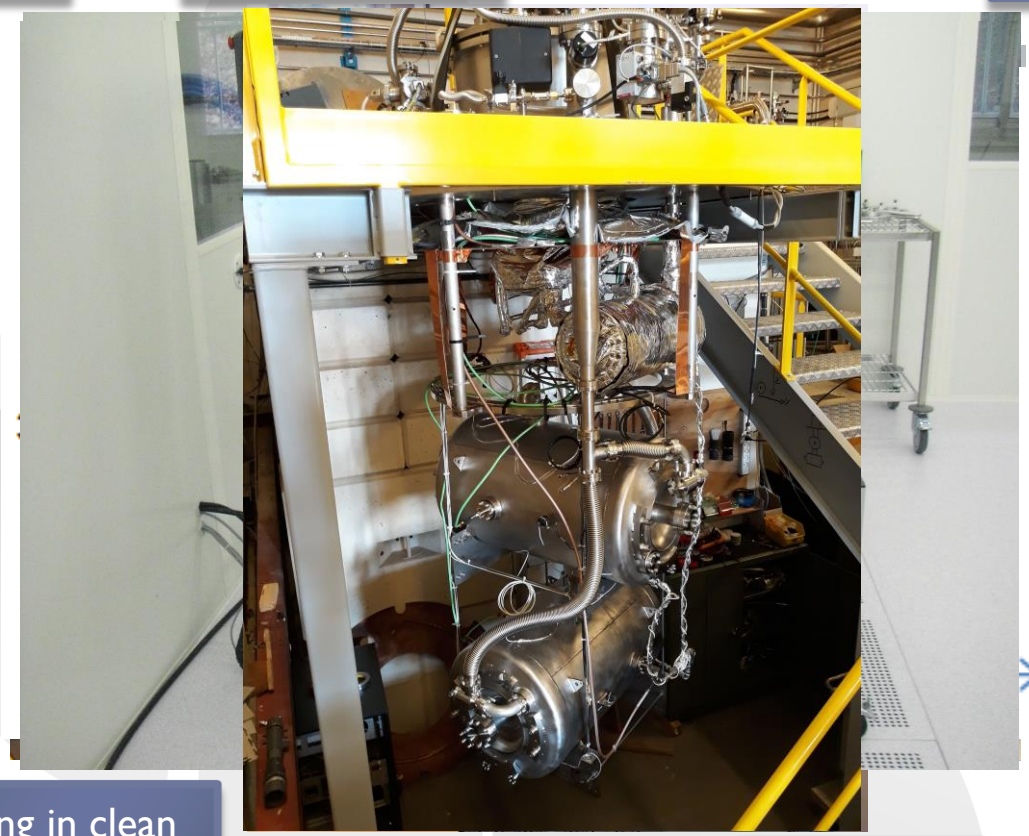
Processing capabilities at IJCLab : SUPRATECH Platform

US Bath + detergent (cavity + tank)

Deionized water rinsing (cavity + tank)

BCP (cavity)

HPR (cavity)



Drying in clean room (cavity + tank)

Furnace

BCP (cavity)

HPR (cavity)

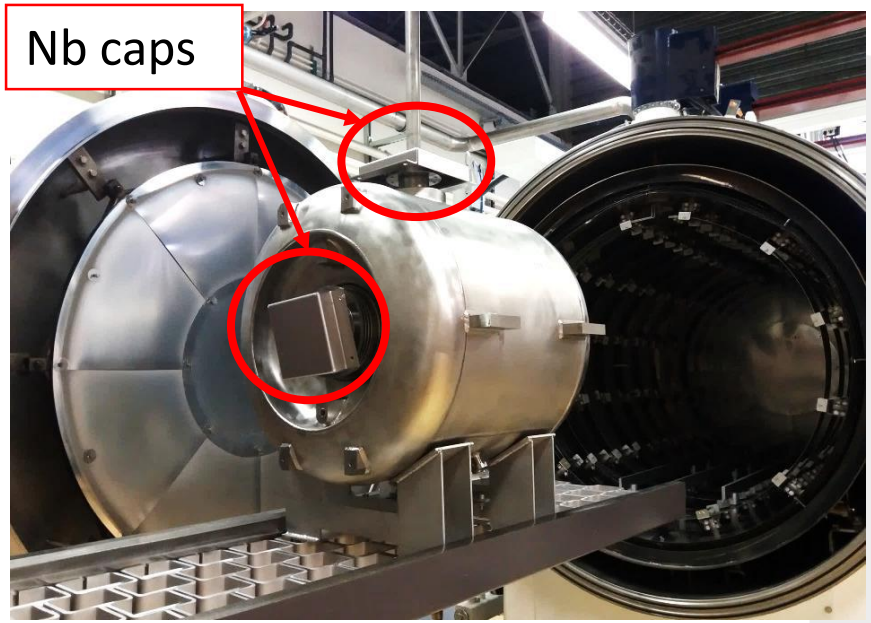
Drying in clean room (cavity + tank)

Assembly + VT test

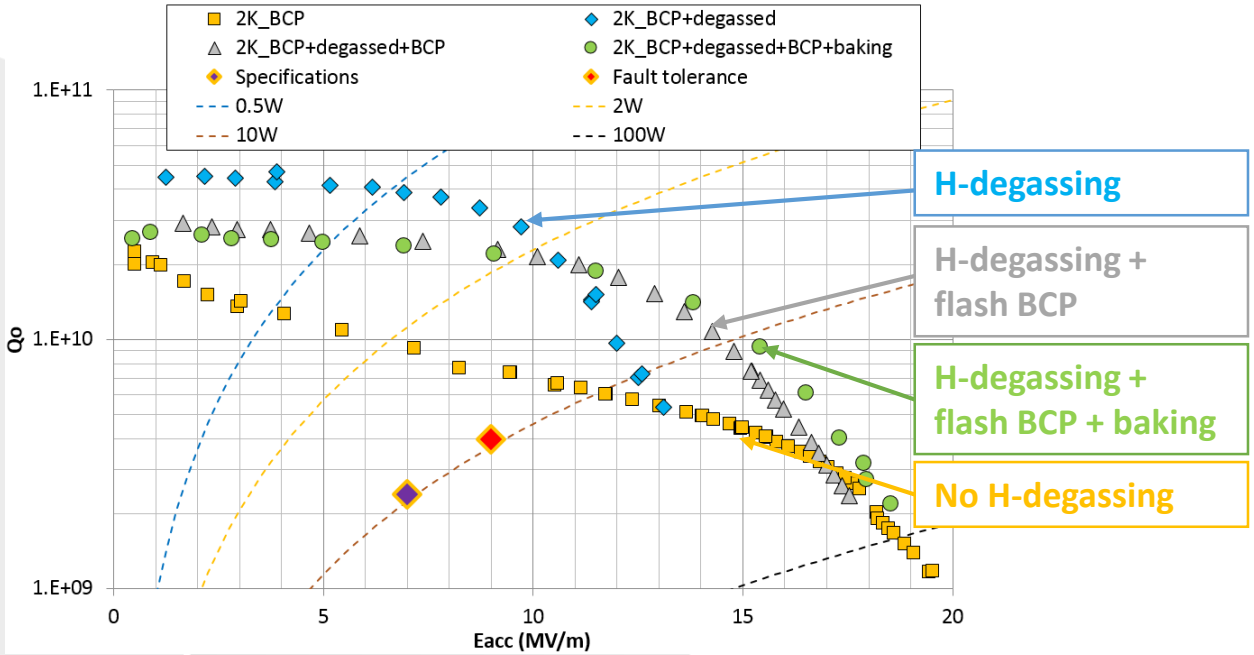
Current R&D on surface processing : MYRRHA Project

- No flash BCP after heat treatment

Bulk BCP 150-200 um → HPR → H-degassing 650°C 10h → ~~Flash BCP 20 um~~ → HPR



MYRRHA Simple Spoke Cavity



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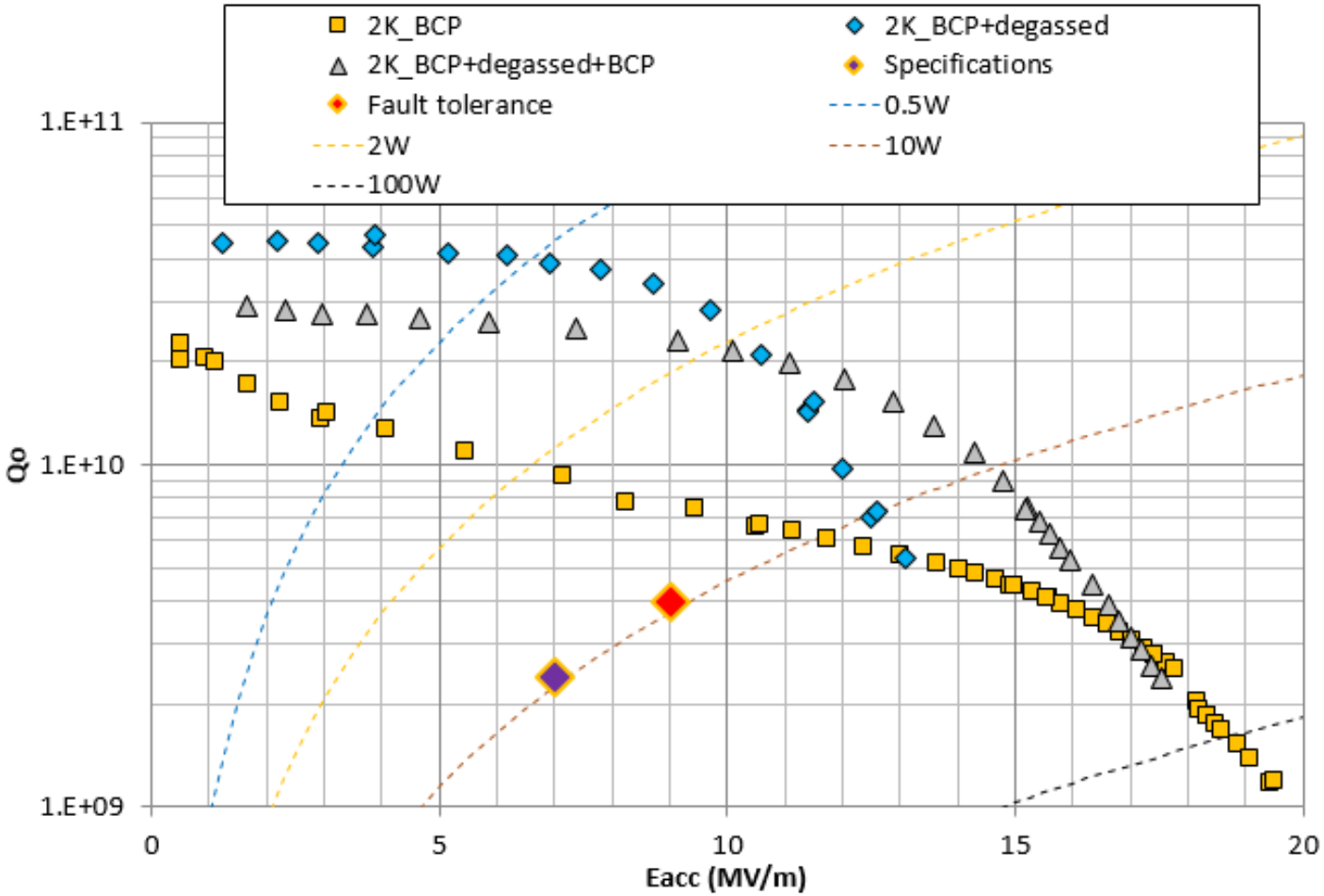
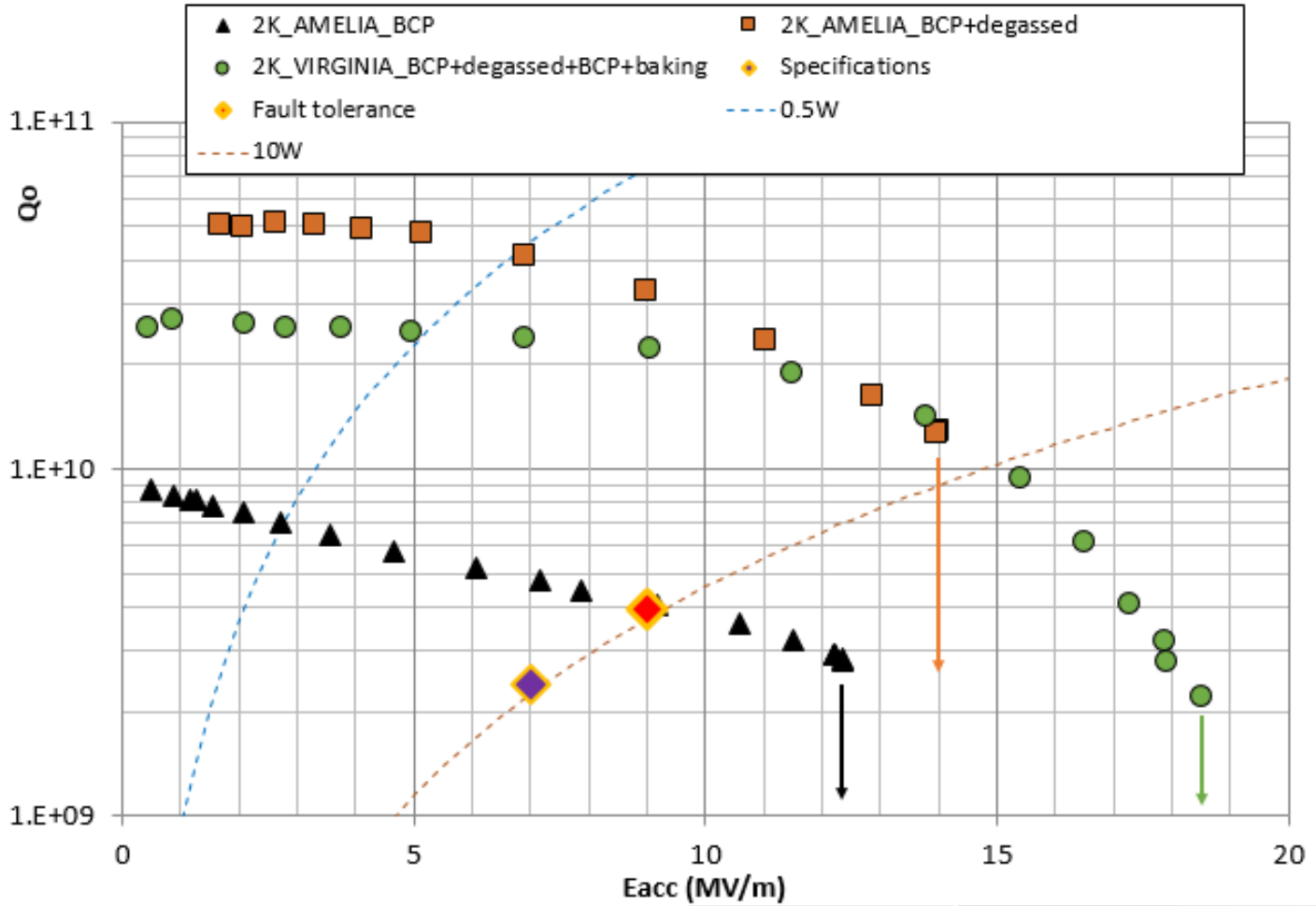


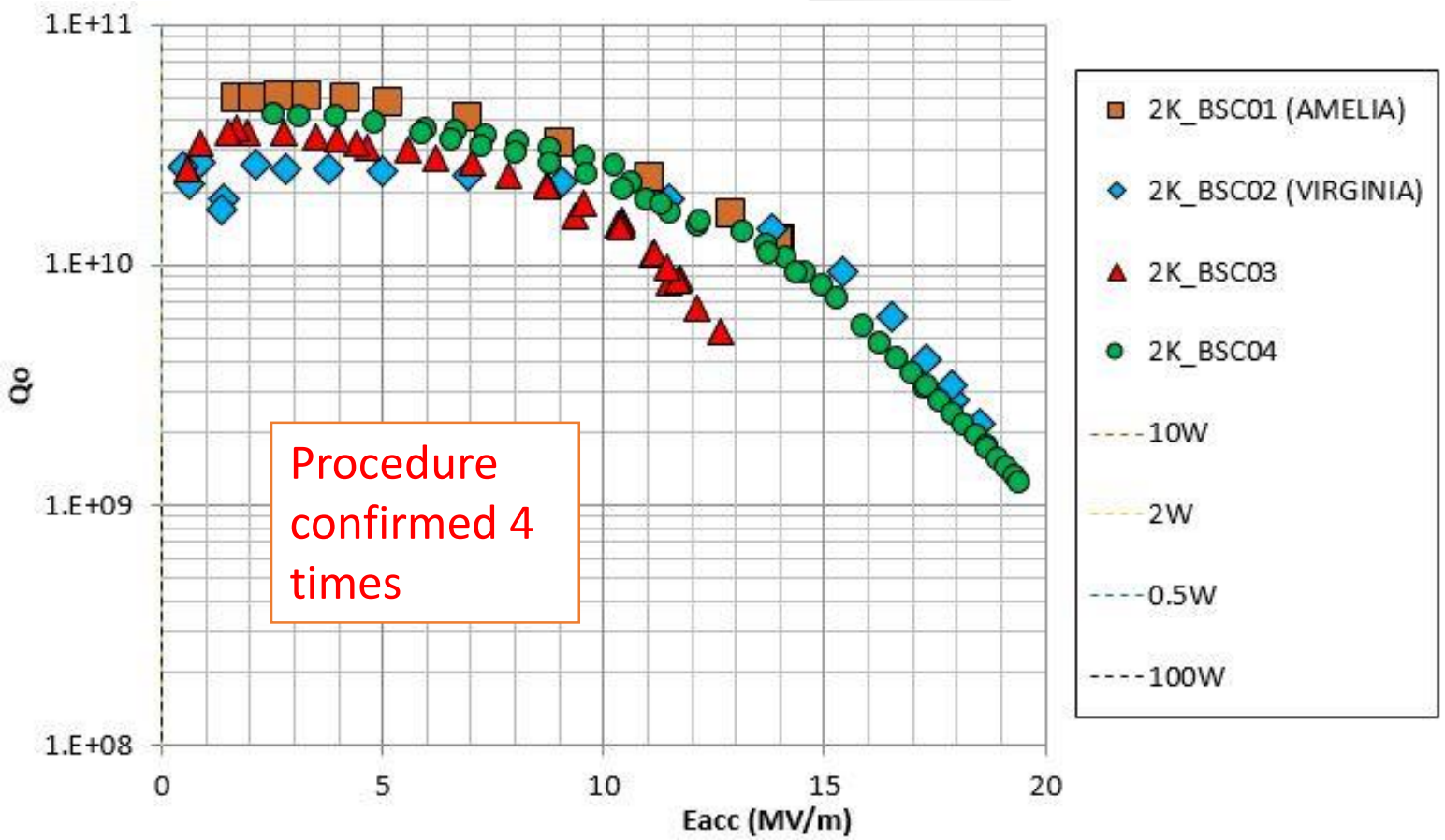
With Titanium tank + Stainless steel flanges

- No flash BCP after heat treatment



With Titanium tank + Stainless steel flanges

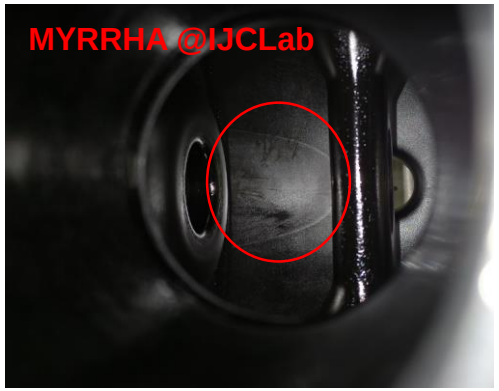
- No flash BCP after heat treatment (except blue diamond)

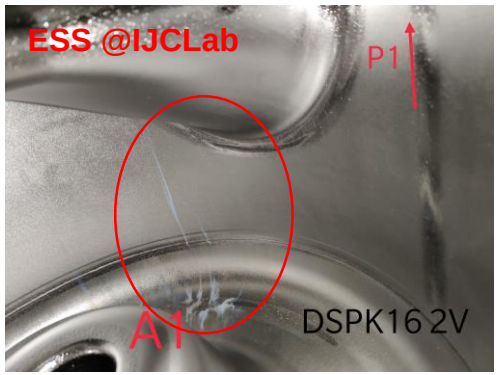


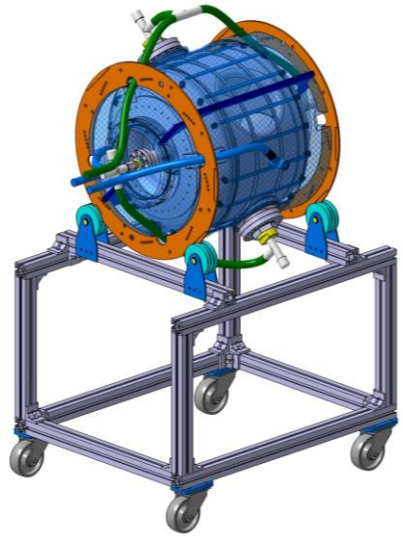
- Better Qo at low field (~ $4^{E}10$)
- Simplification of surface processing (less step => less risks)
- Need to confirm same Qo after frequency tuning (to be tested beginning 2021)

1. Improvement of BCP procedure

- How to have a better homogeneity of material removal ?
- How to avoid surface traces and white marks (coming from bubbles resting)







- Semi-rotational BCP bench (+/- 180°) at ~ 1 rpm
- Allow mixing of BCP mixture during the full process
- Avoid creation of bubbles
- Allow homogeneous water rinsing after acid draining

1. Heat treatment

- Validation of MYRRHA procedure: No Flash BCP after Hydrogen degassing (650°C during 10h)
- Standard baking 120°C 48h is not recommended : no benefit on Qo at operational gradient.
- Short baking 120°C 3h is recommended to reduce multipacting if processing is complicated.